2.0 USER NEEDS

The consequence assessment systems introduced in chapter 1 can serve a variety of applications. While the scope of this document is primarily focused on the emergency preparedness and response needs of the homeland security community, consequence assessments are important in other applications as well. All of these applications utilize the fundamental building blocks of figure 1 and face the challenge of properly employing ATD modeling systems in complex environments, such as urban and coastal areas.

This chapter explores the range of user activities and their specific needs within the area of emergency preparedness and response, while identifying common needs that extend across these diverse application areas. These needs are the principal drivers that determine what the ATD modeling system must provide within any specific application's consequence assessment system. This statement foreshadows a major theme of this report: early and continuing involvement of the user community is essential in the development and product improvement process.

The JAG invited users from local, state, and Federal agencies to discuss their current use of ATD modeling systems, shortfalls in their ability to perform consequence assessment, and how their needs and requirements could be better met. These representatives included firefighters, state emergency managers, and Federal emergency responders and managers. Their perceptions of current capabilities and needs are the basis for most of this chapter.

2.1 The Emergency Preparedness and Response Environment

The emergency preparedness and response environment includes a number of activities during which consequence assessment of an airborne hazard is relevant. Planning activities start in anticipation of a specific incident to help everyone prepare to respond. Response activity begins when an incident occurs. Response activity then transitions into recovery activity. Incidents that involve the release of an airborne hazardous material (HAZMAT) can range from a relatively straightforward situation that can be handled by local responders to a complex situation that involves elements of all three activities (response, planning, and recovery) and requires resources from many different organizations.

The same personnel may be (and often are) involved in planning, response, and recovery activities. These personnel include:

- The local, state, and Federal emergency responders—law enforcement officers, firefighters and HAZMAT technicians, emergency medical personnel, and on-scene commanders;
- Government officials and emergency managers, many of whom will have important decision-making roles; and
- Federal agency decision makers, executing their operational missions.

For domestic incidents of national significance, the roles and responsibilities of the Federal agencies are defined in the National Response Plan and its associated annexes (DHS 2003). The incident management process is described in the National Incident Management System. Requests for Federal assistance and information flow up through the local jurisdiction's (e.g., city or county) emergency operations center to the state level, and then to the Department of Homeland Security (DHS). In domestic incidents of national significance, such as terrorist incidents and other high-visibility, multi-jurisdictional events, DHS may designate a Federal officer to serve as the local DHS representative and provide senior leadership, strategic guidance, and Federal operations integration (DHS 2004).

Release Event
What was released?
When?
Where?
How Much?

Observations
Direct
Sensor
Casualty

Risks
How many?
For how long?

Consequence management
How to minimize and/or manage impact?

FIGURE 2. Questions of concern to users of ATD modeling predictions for emergency preparedness and response.

For an incident involving the atmospheric release of a hazardous material, these users all need answers to the questions shown in figure 2. These fundamental questions remain relevant whether the hazardous release incident is small in scale and handled entirely by local response personnel or becomes an incident of national significance, spanning multiple jurisdictions and requiring Federal response support.[1] Current capabilities to answer these questions vary among Federal, state, and local response agencies. Locales that have industrial or manufacturing facilities, containing substantial amounts of hazardous materials, may be better prepared in terms of personal protection equipment, sensors, and stand-alone modeling capability than those without such hazards. Military and other Federal installations that store or handle hazardous material may have capability to respond to CBRN releases. The military may also provide support services to civilian agencies as an integral element of its homeland defense mission.

Four common themes recurred in the comments from most of the users who spoke with this JAG:

[1] The 2002 annual report of the National Atmospheric Release Advisory Center (NARAC 2002) states, "Effective preparation for and response to the release of toxic materials hinge on accurate predictions of the dispersion, ultimate fate, and consequences of the chemical or biological agent. Of particular interest is the threat to civilian populations within major urban areas, which are likely targets for potential attacks."

- The safety of people is the first priority.
- All emergencies are local, and most are short-lived.
- The end user of the ATD results needs actionable information.
- Inconsistent data products and distribution protocols can cause confusion and inefficiencies in the emergency response.

Not surprisingly, one of the first and most important needs expressed by emergency responders is the need for effective communication and early indication of where the contaminant is going. Equally important is gaining an understanding of where it is likely ***not*** to go. A communications link between the HAZMAT or other emergency personnel and personnel with ATD expertise is often preferred to having the modeling capability "onboard" or at the scene. A "reach-back" capability is desirable because responders are busy dealing with public safety issues including medical response, potential evacuation, and incident characterization. They do not have the resources to run models and interpret results.

Emergency responders requested more useful and uniform products and a standard protocol for distribution and display of hazard predictions to the response community. They emphasized the need for established procedures to rapidly disseminate hazard area predictions to all levels of the response team. The use of GIS-based displays with overlays of near real-time hazard information could be especially important for large-scale incidents, involving multiple response agencies and potentially affecting large segments of the local and/or regional population.

The products need to be easily displayed and uniform in content. While users wanted a reach-back capability when needed (for example in a major incident), they also want an on-scene capability for making rapid decisions during smaller scale incidents. Above all, emergency responders asked for the capability to deliver the information needed into the hands of those working to save lives.

The user panel expressed the following key needs.

- Improvements are needed in the national capability for consequence assessments for preparedness and response applications:
  - Capability for modeling more than one substance at a time;
  - Realistic planning scenarios that can be built quickly and simply, to include a variety of hazards and local weather scenarios;
  - Scenarios that include common industrial chemicals, especially ones that could be weaponized;
  - Planning scenarios for CBRN agents, utilizing local building terrain and weather profiles;
  - Improved infiltration models; and
  - Capability for modeling flammability and explosivity.

- Information must be displayed in the emergency manager's display system (which may or may not be GIS-based) in accordance with the organization's standard operating procedures.
- A standardized set of products should be tailored to the needs of the particular end user:
  - Multiple product sets for multiple users;
  - Regular updates;
  - Realistic predictions which depict forecast uncertainty; and
  - Timely products—the key to saving lives.
- Training and coordination among Federal, state, and local responders are critical to efficient communications during an event.
- Users must be brought into the development process early and often.

2.2 User Needs in Other Applications of ATD Modeling Systems

2.2.1 Military Applications

The primary military requirements for ATD modeling *in theater* are for force protection and civilian population protection. CBRN materials are expected in modern military encounters on the battlefield. In data-denied areas, the military needs improved capabilities to sense weather and hazard parameters within an operational area. Accurate guidance on the use of hazard protection equipment (protective garments, masks, etc.) to defend against chemical or biological agents is critical for conducting military operations.

The key questions of importance to emergency preparedness and response (figure 2) are still the questions that military users need to answer, but the form and content of a useful answer may be different. For CBRN incidents, military applications involve planning and response phases similar to those for civil emergency preparedness. However, the resultant actions may differ and will be driven by military needs.

Meeting the needs specific to military applications will require:

- Improving current capabilities of weather-parameter and hazard-sensing systems that can be remotely deployed and monitored;
- ATD planning for installation protection and for joint and coalition operations, covering both deliberate releases (hostile actions) and accidental releases (e.g., destruction of enemy munitions containing CBRN and accidents during the removal or storage of CBRN-containing materiel); and
- Enhancing the capability to acquire and process the weather and hazard-sensor data; including assimilating the data into meteorological and ATD models.

2.2.2 Air Quality Monitoring Applications

The 11th Prospectus Development Team of the U.S. Weather Research Program observed in its July 2003 final report that there are at least three groupings of users of air quality information: the public, decision makers, and researchers (Dabberdt et al. 2004). The public is the largest user group, and the broadcast media provide the means of disseminating air quality information from its official source to the public. Decision makers that use air quality forecasts include Federal agencies, civil authorities (e.g., state and local departments of health), emergency response organizations, and the private sector (power, transportation, health care, and others). Among the Federal agencies that use these forecasts are the U.S. Environmental Protection Agency (EPA), the U.S. Forest Service in the Department of Agriculture, and the National Park Service in the Department of the Interior. Both public and private sector organizations use air quality forecasts to authorize and plan operations such as prescribed burns or pollutant-emitting operations at power plants and chemical manufacturing plants. Researchers who use air quality forecasts include air quality and environmental scientists, regulatory scientific advisors, and atmospheric scientists conducting field measurement studies.

The key questions of importance to emergency response also apply to air quality users; however, the form and content of a useful answer may be different. There is likely to be more emphasis on the capability for planning, and some of the decision elements involved, such as regulatory considerations, differ because the reasons for interest in air quality only partially overlap with the objectives of emergency response. Forensic applications in air quality are similar to those used in emergency response when ATD models are used to backtrack from observed concentrations to a release point. This application of ATD modeling may be necessary when the actual amounts and chemical makeup of the source material are unknown, as in an accidental release. Other uses of ATD models in air quality assessment are distinct from the way these models are used in a consequence assessment system.

For air quality forecasting, three-dimensional meteorological and chemical observations and advanced data assimilation methods are essential. In addition, meeting ATD modeling needs specific to air quality applications will require:

- Improved physical understanding of the atmospheric boundary layer (ABL);
- Better land-surface models;
- Better representation of winds and turbulence across varied spatial and temporal scales;
- Better understanding of clouds and cloud processes that affect chemical fate and transport; and
- Improved capabilities for estimating uncertainty and predictability and for evaluating models.

Information about other pollutants, including particulate matter, is important when considering the long-term health impacts on the population. For example, the air quality standards for fine particles are calculated using an annual average because national ambient air quality standards are set for pollutants that the public is generally exposed to for long periods of time. A shorter-term average standard would be more helpful when assessing the impact from short-term events or peak concentrations in long-term events. In the case of a fire or some other large source of particulates, the general practice is to move people away from the most intense concentrations of smoke. In responses to events that last on the order of days to a year (e.g., a landfill fire), however, managers need guidelines to decide how much short-term exposure a population can tolerate at any given time.

2.3 ATD Information Required for Hazard Response Decisions

The preceding sections showed that, across a range of applications for ATD modeling systems, the basic questions are the same. The user needs to know what the hazard is, when and where it is a threat to people (or other consequences), and the seriousness of the potential health and safety impacts to people and the potential environmental impacts.

For both health and environmental issues, the consequences can range from acute effects of short-term exposure to more slowly developing consequences of long-term exposure to levels too low to produce acute effects. For acute effects, spikes in the concentration of an airborne hazard are typically of interest. Therefore, the ATD model prediction needs to provide information on the spatial variability in hazard concentration on a time scale consistent with the time required to produce an acute effect. To assess effects from longer-term exposure to lower concentrations of a hazard, the time-averaged concentration of the hazard is needed. Many potential airborne hazards, including most CBRN agents, can potentially have acute and long-term effects, so both kinds of information are often relevant to the user.

Flammable materials are another class of potentially hazardous materials. When mixed with air in the right concentration range (i.e., between lower and upper concentration limits for the particular material), the material can explode if a source of ignition is present. If other combustible materials are within or near the explosion volume, the explosion can set off a rapidly growing fire. Users of a consequence assessment system for this class of hazards want to know when and where the concentration could be within the explosivity limits. This requirement is much like that for acute exposures—spikes in the airborne concentration at a time and place can be enough to reach the lower limit of explosivity.

For all of these consequences, the bottom line for the ATD modeling system is that ***the users want to know about the concentration of the hazard as a function of space and time***. In many instances, the user will want to know about both the peaks in the concentration at small time and space scales and the time-averaged concentration at spatial scales relevant to the consequence of interest. ATD predictions of concentration as a function of space and time must meet accuracy objectives for all places and conditions of concern, especially coastal urban areas. Physical processes to which ATD models are sensitive must be adequately treated, including land-sea breezes, urban heating effects, and urban effects on local winds. In densely populated regions of concern, small changes in the predicted hazard area can have substantial impacts on user decisions.

2.4 Constraints and Tradeoffs in ATD Modeling to Meet User Needs

Planning, response, and recovery activities have different constraints on timeliness for receiving a relevant prediction and on the comprehensiveness and completeness required for a prediction to be useful. The optimal tradeoff among these constraints will be different for different activities, different applications, and even specific characteristics of an incident (e.g., the hazard released and its consequences of interest, the amount released, the location of release, and the areas potentially affected).

As emphasized above, timeliness is the most important constraint for the responder but not the only one. One of the most important needs that emergency responders expressed to the JAG is for early indication and effective communication of the plume direction. Equally important is gaining an understanding of where the plume is likely ***not*** to go.

Most responders desire a comprehensive *reach-back* capability, which allows the local ATD modeler (or the on-scene user) to access technical support in getting predictions from the ATD modeling system that reflect the specific characteristics of the incident at hand. A single, direct line of contact from the incident command post to the supporting expertise is needed, rather than a complicated system that requires an expert to operate at the front lines. Most responders prefer an ATD modeling tool that is simplified for the response environment. They are too busy dealing with the immediate threats to health and safety to run complex models or to analyze results that do not tie directly to the decisions confronting them.

Specific emphasis on meteorological studies for planning purposes should be given to coastal zones, complex terrain, and urban environments where local heterogeneities have significant impact on dispersion. Users were especially aware of the special challenges raised by urban environment*s*. In urban areas, the presence of buildings and other structures affects not only the flow fields but also the structure and intensity of atmospheric turbulence. The R&D and test and evaluation communities need to seek user input on these urban challenges, the practical approaches users have found to dealing with them, and the kinds of information that would be of most benefit. Accurate databases on the built environment are required to model these surface-atmosphere interactions at scales relevant to ATD in urban environments.

Standard dispersion methodologies are based on descriptions of processes developed in the absence of buildings and urban street canyons. The influence of such urban complexity is known to be major, but relatively little is known concerning the best way to capture the consequences of site-specific surface features in the descriptions of turbulence used in dispersion calculations. In addition, building infiltration and exfiltration should be represented.

2.5 "If I Can't Have Certainty, Tell Me How Bad It Could Be, and Where"

Emergency responders do not want ATD model predictions couched in terms of mathematical measures of uncertainty or highly technical statements about probability. They do not know how to use such information. These measures of uncertainty bear no immediate and clear relationship to the decisions for which the users want information on hazard concentration as a function of space and time. This point was made most strongly by the first responders among the users who met with the JAG. While some decision makers may understand how to use uncertainty estimates, this fact also generally applies to planners and recovery operators as well.

The fundamental issue for the model developer can be expressed simply: Users want certainty in the information they get, so they can act quickly and decisively. The nature of the modeling situation (to be discussed in section 3.1), however, means that no ATD modeling system can provide predictions with certainty, at least not for situations of interest to real-world users.

Because users understand that there are limits to ATD modeling capabilities, they apply their intuitive estimate of uncertainty in order to err on the side of safety. A better option than relying on an intuitive safety margin is for users to have information on uncertainty interpreted into a form they know how to use. Rather than mathematical measures of uncertainty or probability, users asked for answers to these kinds of questions:

- What is the [reasonable] worst case to prepare for, and where could it occur?
- What areas are safely out of danger?
- Where could thresholds of interest (e.g., concentrations with lethal or other acute effects, longer-term exposure thresholds, explosive concentrations) be exceeded and when?

Many users are aware of the uncertainties in source characterization, in other model inputs such as fine-scale winds and land cover, and in modeling simplifications made to get results within time constraints. In many cases, users are dealing with the same types of uncertainty in their decisions. Knowing how users understand and work with these uncertainties can help developers find ***useful*** ways to present prediction uncertainties and probabilities to the user.

Reducing the uncertainty in ATD model predictions is an obvious goal for model developers. At the same time, model developers, users of model predictions, and all who assess progress in improving consequence assessment capabilities must understand that there will always be uncertainties in modeling complex, dynamic systems. The task for the modeling system researcher-developer is first to identify the sources of uncertainty in a given modeling system and provide reasonable measures of the uncertainty in a given set of predictions from the system. The second task—which may be the harder of the two because we know less about it—is to ***find ways to communicate to the user the implications of these uncertainties for that user's decisions.*** It is not enough to provide measures of uncertainty that are defensible within the model developer's world. Developers and representative users from the range of applications to be served will have to work together to determine how to make this essential information useful. The next task is to provide users with tools that meet their needs, which must be accomplished as part of development. The transition of R&D products into working tools must begin while the tools are still under development and before they are declared operational.